इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 9692-4 (1987): Guide on maintainability of equipment, Part 4: Test and diagnostic procedures [LITD 2: Reliability of Electronic and Electrical Components and Equipment]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA JURIS NON EXCUSAT

PROTECTED BY COPYRIGHT

IS : 9692 (Part 4) - 1987
(Reaffirmed 2002)

Indian Standard

GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART 4 TEST AND DIAGNOSTIC PROCEDURES

UDC 621·38·038 + 621·31-7 (026)

© *Copyright* 1987

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 4

July 1987

Indian Standard

GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART 4 TEST AND DIAGNOSTIC PROCEDURES

Reliability of Electronic and Electrical Components
and Equipment Sectional Committee, LTDC 3

Chairman	*Representing*
Prof S. Sampath	Indian Institute of Technology, Kanpur
Members	
Additional Director, Standards (S&T), RDSO	Railway Board (Department of Railways), (Ministry of Transport)
Joint Director, Standards (S&T)-III, RDSO (*Alternate*)	
Shri S. P. Bhatikar	All India Radio, New Delhi
Shri J. S. Sood (*Alternate*)	
Shri V. C. Bhandari	Instrumentation Ltd, Kota
Shri I. S. Sulakh (*Alternate*)	
Shri Charanjit Singh	Hindustan Aeronautics Ltd, Hyderabad
Shri R. Parthasarathy (*Alternate*)	
Dr P. K. Dutta	Peico Electronics & Electricals Ltd, Bombay
Shri S. P. Ghokkalingaram (*Alternate*)	
Shri P. K. Jain	Electronics Components Standardization Organization, Ministry of Defence
Shri G. S. Pai (*Alternate*)	
Shri R. K. Jayadev	Overseas Communication Services, Bombay
Shri Daljit Singh (*Alternate*)	
Shri M. S. Kamath	Indian Electrical Manufacturers' Association, Bombay
Shri T. C. Gosalia (*Alternate*)	
Shri C. Krishnamurthy	Bharat Electronics Ltd, Bangalore
Shri N. Dhansekharan (*Alternate*)	
Shri S. P. Kulkarni	Radio Electronic & Television Manufacturers' Association, Bombay
Shri S. M. Khursale (*Alternate*)	
Shri Lakshminarayana	Indian Telephone Industries Ltd, Bangalore
Shri V. Muthaiah (*Alternate*)	
Shri K. M. Mankad	Electronics Corporation of India Ltd, Hyderabad
Shri B. Bhaskar Rao (*Alternate*)	

(*Continued on page* 2)

© *Copyright* 1987
BUREAU OF INDIAN STANDARDS
This publication is protected under the *Indian Copyright Act* (XIV of 1957) and reproduction in whole or in part by any means except with written permission of the publisher shall be deemed to be an infringement of copyright under the said Act.

(*Continued from page* 1)

Members	*Representing*
Brig R. K. Mehra	Ministry of Defence (DGI)
Lt-Col S. P. Murgai (*Alternate*)	
Shri D. C. Mehta	Directorate General of Civil Aviation, New Delhi
Shri R. V. Israni (*Alternate*)	
Dr M. B. Misra	In personal capacity (*Department of Electrical Engineering, Indian Institute of Technology, Kharagpur*)
Shri B. C. Mukherjee	National Test House, Calcutta
Shri R. N. Mukherjee (*Alternate*)	
Shri K. R. Anandakumaran Nair	Lucas-TVS Ltd, Madras
Shri C. Ranganathan (*Alternate*)	
Shri D. V. Petkar	Bhabha Atomic Research Centre, Trombay
Shri A. K. Babar (*Alternate*)	
Shri K. Ramgopal	ISRO Satellite Centre (ISAC), Bangalore
Shri Siharan De (*Alternate*)	
Shri P. K. Shukla	Centre for Aeronautical System Studies and Analysis (CASSA), Ministry of Defence
Shri R. Soma Sundaram	Directorate of Technical Development and Production (AIR), Ministry of Defence, New Delhi
Shri R. S. Yadav (*Alternate*)	
Shri H. C. Tewari	Central Electricity Authority, New Delhi
Shri D. P. Sinha (*Alternate*)	
Shri T. S. Vasudevan	Department of Telecommunication, New Delhi
Shri A. V. Koundinya (*Alternate*)	
Dr R. P. Wadhwa	Department of Electronics, New Delhi
Shri E. G. Nagarajan (*Alternate*)	
Shri N. Srinivasan, Director (Electronics) (*Secretary*)	Director General, BIS (***Ex-officio Member***)

Indian Standard

GUIDE ON MAINTAINABILITY OF EQUIPMENT

PART 4 TEST AND DIAGNOSTIC PROCEDURES

0. FOREWORD

0.1 This Indian Standard (Part 4) was adopted by the Indian Standards Institution on 11 February 1987, after the draft finalized by the Reliability Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This guide is intended to make recommendations for the standardization of maintainability practices, and to stimulate ideas in the maintainability field. Organizations acquiring items will find the guide useful in assisting them in defining maintainability requirements and associated programmes. Item suppliers will benefit from use of the guide, gaining an understanding of the requirements for achieving and verifying maintainability objectives.

0.3 In preparation of this standard, assistance has been drawn from IEC Doc 56 (Sectt) 190 'Draft — Guide on maintainability of equipment, Section 4 Diagnostic Testing', issued by International Electrotechnical Commission (IEC).

1. SCOPE

1.1 This standard (Part 4) provides concepts related to test functions which are needed for proper operation and maintenance of systems and describes methods to develop them.

2. TERMINOLOGY

2.0 For the purpose of this standard the following terms and definitions in addition to those specified in IS : 1885 (Part 39)-1979* shall apply.

2.1 Calibration — The application of specifically known and accurately measured input to ensure that an item will produce

---

*Electrotechnical vocabulary: Part 39 Reliability of electronic and electrical items (*first revision*).

specifically known output which is accurately measured or indicated. Calibration includes adjustment or recording of corrections, as appropriate.

2.2 Check — An examination to determine the functional capability or physical integrity of an item.

2.3 Functional Check — A quantitative check to determine if one or more functions of an item perform within specified limits.

2.4 Condition Monitoring (Status Monitoring) — A primary maintenance process under which data on the whole population of specified items in service is analyzed to indicate whether some allocation of technical resources is required. Not a preventive maintenance process, condition monitoring allows failures to occur, and relies upon analysis of operating experience information to indicate the need for appropriate action.

NOTE — Failure modes of condition monitored items do not have a direct adverse effect on operating safety.

2.5 Test Procedure — Individual tests performed in a sequence or to a schedule in order to obtain values of stated parameters. A test procedure consists of individual tests.

2.6 Testability — A design characteristic which allows the status (operable, inoperable, or degraded) of a unit (system, subsystem, module or component) and the location of any faults within the unit to be confidently determined in a timely fashion.

2.7 Test Effectiveness — An overall testability measure which includes hardware design built-in-test (BIT) and test program set (TPS) design. Test effectiveness measures include, but are not limited to, test thoroughness, test accuracy, and test rapidity.

3. GENERAL

3.1 Diagnostic testing constitutes an important part in the operation and maintenance of a system or equipment. The maintenance concept contains all these types of tests deemed necessary for this purpose. Some or all of the following may by required:

a) Monitor certain perameters or the operation during the operation in order to assure continuity or their being within specified limits and to foretell their trend so that possible corrective action can be taken during scheduled down times;

b) Check certain parameters during normal down times in order to determine that the item will function normally during the required operating time or to subject the item for anticipated fault detection;

c) Perform a detection or analysis operation to isolate a part or component determined to be subject to imminent failure or that has failed; and

d) Perform a check of the necessary parameters following repair work to ensure their being within specification limits and to check item normal operating parameters to ensure that the item has been restored to normal operational status.

Procedures may be carried out manually or with test equipment which may contain different amounts of automation.

3.2 It is desirable that the design of an item facilitates the performance of the tests described above. In case of a new design, this may be accomplished by incorporating appropriate testability features in the design; otherwise, some features facilitating testing can be added, but there is less flexibility in the ability to change the maintenance concept. It is an important element of a maintainability programme to assure that in each case appropriate fault detection and localization procedurs are available and capable of supporting maintenance testing.

3.3 Diagnostic tests which are introduced as part of the maintenance process of an item must always be compatible with the overall maintenance concept. It is therefore essential that the maintenance concept be defined. This definition must include:

a) *Level of maintenance* — Specify replacement level within the item at which maintenance action will be accomplished-sub-assembly, module component assembly, or individual part along with item maintenance adjustment requirements.

b) *Line of maintenance* — Identify the location where maintenance will be accomplished-item operational site, centralized maintenance facility, item suppliers plant, etc.

c) *Test equipment and maintenance facilities* — Specify the test equipment and other maintenance facilities to be used in the fault detection and location process.

d) *Function criticality* — Describe the functional criticality of the item's performance and the need for rapid restoration along with budget constraints.

e) *Test interfaces* — Specify the item interface with test devices and other measurement equipment.

f) *Test environment* — Identify environment in which tests will be accomplished.

g) *Personnel* — Define the number and skill requirements for maintenance and operational personnel who will be performing the test and diagnostic procedures.

h) *Software support* — Identify restrictions on special test facilities or special computer programs (compiler : test diagnostics, etc), required to use the fault detection and location procedures.

j) *Continuous monitoring of critical functions* — Identify those functions which for safety or operational reasons are being continuously monitored, thus influencing the test requirements.

4. TECHNICAL DIAGNOSTICS

4.1 Condition Monitoring

4.1.1 Condition monitoring is a type of diagnostic testing performed in order to determine the operational status of an item. It is often accomplished by test systems essentially dedicated to perform this function on a continuous or periodic sampling basis. These tests are usually designed to give a go/no go answer. In the simplest form it may be an indicator light signifying an up state or measuring a parameter, where it is required to be within given limits.

4.1.2 The selection of parameters depends on the purpose of the monitoring (safety, operational status, preventive maintenance). The requirements may thus come from conditions of intended use or its environment, or from needed assurance of item availability stemming from the condition of some critical parts or components or the need to minimize down times.

4.2 Functional Check — The purpose of a functional check is the comparison of individual item functions (movement, flow, temperature, pressure, voltage, etc) with specified performance standards. This requires adherence to detailed test procedures.

4.3 Fault Localization

4.3.1 If it has been shown by condition monitoring or functional check that an item does not perform within stated limits, then fault localization is performed to diagnose the failure, identify the unit requiring rapair or replacement.

4.3.2 Similar test procedures may be used for condition monitoring, functional check and fault localization. The difference stems not from the type of test action but rather from the fact that fault localization tests tend to require more information about sub-item functional status. As a result, fault localization procedures tend to be more detailed, and contain more individual test routines. For fault localization, the sequence of testing may be conditioned on the results of prior tests, while condition monitoring and functional check mainly are high level tests normally performed in a fixed sequence.

4.3.3 Usually there is a pressing need to expedite these operations to that the system/equipment can be returned to an up state with the least possible delay.

4.3.4 Fault localization can be performed on all maintenance levels with similar test routines, depending on the degree of item breakdown for fault isolation purposes.

4.4 Calibration

4.4.1 Calibration is a specific diagnostic test function with the purpose to ensure that an item remains in or returns to an operational condition. This is accomplished by testing and appropriately balancing individual subunit performance levels.

4.4.2 Calibration can be the last step in a repair process, or it can be performed without any preceding repair action on a periodical basis by adjusting for internal imbalances.

5. SPECIFIC REQUIREMENTS

5.1 Sources of Requirements

5.1.1 Requirements for condition monitoring, fault detection and location procedures are given from two separate sources:

a) *Equipment availability requirements* — These have been given during the definition phase and have been further refined during design and development. The maintenance concept is specified at this time in correlation with what is delegated to be done by maintenance during the operational phase of the equipment.

b) *Test effectiveness* — Test effectiveness, as measured by the accuracy, thoroughness, and rapidity of the application, reflects on the ability to meet the availability requirements. Test engineering inputs are necessary to the equipment designer to evaluate the necessary procedures. The maintenance plan must reflect the intended implementation including the allocation of necessary test sets and instructions to the assigned maintenance levels.

5.2 Test Effectiveness Requirements

5.2.1 The effectiveness of a test procedure encompasses the accuracy, thoroughness and rapidity with which the procedures may be applied to an item. The test procedures as applied to the item under test include an evaluation of the combination of test equipment, and test access of the item.

5.2.2 Major characteristics which can be measured include:

a) *Accuracy of fault detection* — This attribute is a probability and is defined as follows ratio of the average number of faults correctly verified to the average number of faults indicated by the test procedures.

b) *Fault locating thoroughness* — A measure which expresses the degree to which the test procedure can identify or reveal all possible faults within an item. It is expressed as the ratio of the number of sub-items identifiable to the total number of replaceable sub-items as defined by the maintenance policy.

c) *Test rapidity* — Expresses the mean time required to perform the test procedures. It is represented by the product of the average number of test steps required and the average time to perform an individual test.

5.2.3 All test parameters must be considered in context with Life Cycle Costs.

5.3 Test Procedure Requirements

5.3.1 Test procedure requirements address the following characteristics:

a) Test interface devices,

b) Supporting test equipment,

c) Maintenance facilities, and

d) Personnel skills.

5.3.2 Tests must be designed so that the item is not damaged from the test loading. Also cost, supportability, availability and portability of the test resources are factors to be considered.

5.3.3 Finally the ability to test while operating or the consequences of performing tests where the operation must be stopped or the item removed from characteristics of concern.

6. METHODS AND PROCEDURES

6.1 Specification of Testability and Test Parameters

6.1.1 If the item user determines that the testability and test parameters are of major concern, action should be taken to state them as contractual requirements. This is accomplished by specifying:

a) testability design requirements in terms of design criteria for special testability features,

b) testability program requirements (planning aspects, methods and procedures for testability analysis, test and evaluation),

c) factors associated with the maintenance concept (maintenance conditions and constraints, test environment and interfaces), and

d) test effectiveness parameters in terms of minimum acceptable values for test accuracy, thoroughness and rapidity, including the requirements for assessment and validation and the acceptance methods.

6.1.2 Typically, these parameters would be specified and evaluated for the total item. However, if significant difference in test, maintenance or design concepts exist, multiple values may be required.

6.2 Design for Testability

6.2.1 Testability is a design discipline which provides for design features supporting tests. As a minimum, the following design features should be considered:

a) *Functional partitioning* — Whenever possible, each function should be implemented on a single replaceable item to make fault isolation straightforward. If more than one function is placed on a replaceable item, provisions should be made to allow for the independent testing of each function.

b) *Physical partitioning* — The physical partitioning of a system into items should be based, in part, upon the enhancement of the fault isolation process.

c) *Electrical partitioning* — Whenever possible, each block of circuitry to be tested should be designed to be isolated from circuitry not being tested through the use of blocking gates, tri-state devices, relays, etc.

d) *Initialization* — The system or equipment shall be designed such that it has a well-defined initial state to commence the fault isolation process.

e) *Test control (controllability)* — Special test input signals, data paths, and circuitry shall be incorporated to provide the test systems, whether built in test or automatic test equipment, sufficient control over the internal item or component operation for the detection and isolation of internal faults. Special attention is given to the independent control of clocks, breaking of feedback loops, and tri-state isolation of components.

f) *Test access (observability)* — Test points, data paths, and circuitry shall be incorporated to provide the test system, whether built in tests or automatic test equipment, sufficient signature data for fault detection and isolation within the item.

g) *Part selection* — In selecting between parts, each with satisfactory performance characteristis, preference shall be given to integrated circuits components and assembled items which have satisfactory testability characteristics.

h) *Automatic test equipment (ATE) compatibility* — Each item under test should be designed such that it is electrically and mechanically compatible with selected or available ATE so as to reduce or eliminate the need for a large number of unique and expensive interface devices.

6.2.2 The test design considerations must be taken into accounts as early as possible in the design phase. The testability discipline shall be structured to be complementary and/or responsive with the normal acquisition process.

6.3 Testability Assessment Evaluation and Verification

6.3.1 The assessment, evaluation and verification of testability parameters is an important step in the process of achieving a high test effectiveness. Testability assessment and evaluation is accomplished by preparing a checklist of testability-related design issues which are relevant to the design (*see* **6.2** above) and by scoring the degree of achievement for each design issue. The assessment and evaluation of test effectiveness during design requires that analysis be conducted to determine the capability of the test procedures developed in terms of thoroughness, accuracy, and rapidity. The test thoroughness is a function of the test access internally to the item and the power of the logic contained in the test procedures. Accuracy can be evlauated by identifying the ambiguity associated with failure indication of the number of failed components that may be correctly identified by the proposed test procedures. Test rapidity estimation techniques may be used to determine the time required to exercise the test and diagnostic procedure.

An example for a test effectiveness assessment is given in the Appendix A.

6.3.2 Test effectiveness demonstration may be accomplished as part of a standard maintainability demonstration [*see* IS : 9692 (Part 6)-1983*] by placing a sample of representative failures (one at a time) in an item to evaluate the capability of the test procedures. With proper sample selection, an assessment of the test procedures may be developed in terms of the parameters of accuracy, thoroughness and rapidity.

6.3.3 The test types and procedures developed from the maintenance concept need to be evaluated for completeness. The whole testing concept must be reviewed to determine whether the results from the test will give the required information. This includes reliability and completeness of the results when reviewed against what has already been done during the design and development phase so that the required availability is obtained to the confidence level deemed necessary.

6.3.4 In this context, it is necessary to pay attention to possible harmful effects from loads and stresses on the equipment. These may occur during loading of an item to find if it is within specification limits. Certain tests may be individually harmful due to excessive levels, where others may be so due to repetitiveness.

6.4 Test Documentation

6.4.1 Documentation for maintenance test procedures is typically accomplished by narrative and graphic descriptions contained in the technical data supplied with the item (operating and maintenance manuals). Procedures contained shall be clear and concise and be interpretable by maintenance personnel with training and skill level specified in the maintenance concept. Alternatively, the test may be incorporated into a computer program (s) that can be used to control the sequencing of an automatic test equipment connected to an item.

---

*Guide on maintainability of equipment: Part VI Maintainability verification.

A further alternative is to incorporate the test logic into the item to perform a built-in-test (BIT). Built-in-test is used to perform status monitoring as well as failure detection, although it also facilitates fault location and is sometimes used for that purpose. Each methodology has associated various cost and test capability characteristics which must be reviewed by the customer to select the approach that best meets his needs.

6.4.2 All test procedures shall be validated by the supplier prior to buyer acceptance to assure their accuracy. Validation consists of implementing the procedures as outlined in the documentation to assure that the tests are satisfactory.

6.5 Test Procedures

6.5.1 A test procedure is a series of individual tests. An individual test will require that the following steps be defined and taken:

a) *Preparation for test* — The initial conditions that must be attained to start the test; that is control settings, that configuration, and test facilities required.

b) *Provision of input stimuli* — The input power requirements and test signal to be supplied to the item to do the test.

c) *Performance of test operations* — The manipulation of the item controls or attached test equipment to do the test.

d) *Evaluation of test result* — Evaluation of the test results observed against the requirements to determine if the item is functioning correctly and identify the failed unit or additional tests to be performed.

e) *Recording of date* — Test results are recorded and documented.

6.5.2 In addition to identifying the individual tests, the test procedures shall contain information as appropriate concerning the application sequence and schedule.

6.5.3 Automated procedures contain the same elements as manual except that the tests are initiated and interpreted (in part) by a test system. The test system may be external to the item under test or be incorporated in a built-in-test capability.

6.5.4 The test procedures themselves take the form of coded instructions that are used to control the test logic. The test procedures normally are placed into the test system via some machine readable format; for example, punched cards, magnetic tape, etc.

The item buyer may wish to specify the computer language used to develop test programs.

6.5.5 An important consideration with these systems is the facilities required to maintain and modify the test procedures. Often these procedures require changing; thus it is important that the users have a clear understanding of what is required to accomplish the needed changes. Ideally, the user shall secure not only the test procedures but also any support computer programs required to develop or modify these procedures. Additionally, there may be needs for diagnostic test routines for the automatic equipment itself.

6.5.6 Automated procedures may also require supporting manuals that describe their application and use. Documentation and verification of these manuals are also required.

APPENDIX A

(*Clause* 6.3.1)

TEST EFFECTIVENESS ASSESSMENT

A-1. INTRODUCTION

A-1.1 Some of the analysis methods that may be used for test effectiveness assessment are given below. These methods include maintenance functional dependency chart and the dependency matrix.

A-2. FUNCTIONAL DEPENDENCY CHART

A-2.1 A functional dependency chart can be used to evaluate the access to a system for test purposes. Completed, it can also be used as a fault diagnostic aid and as a means to identify the need for further test points and procedures.

A-2.2 In Fig. 2 the chart shows the relationship between the Fig. 1 system inputs, components, test points and outputs. A square symbolizes an input or output; a circle, a component; and a triangle, a connection.

A-3. DEPENDENCY MATRIX

A-3.1 A dependency matrix provides a convenient tool to analyze the accuracy and thoroughness of test procedures. An example of the dependency matrix is provided in Fig. 3, using the system relationships provided in Fig. 1. In the left half of the figure, the relationship between components, correctly functioning, and the test points is provided that is for test point T3 to test correctly components C, C2 and C3 must be functioning properly.

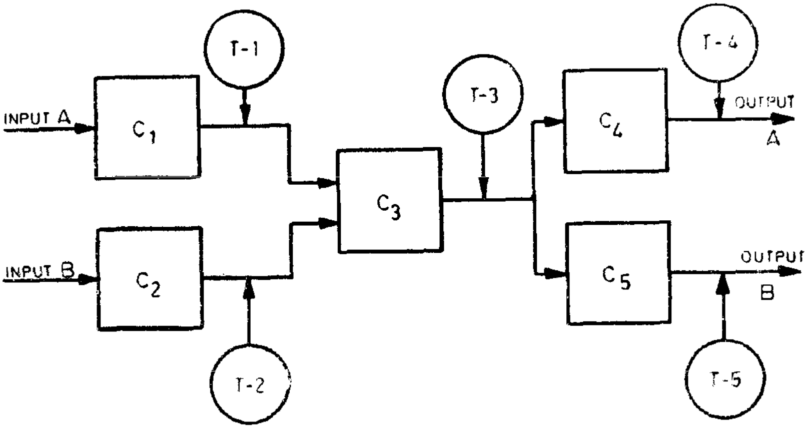

Fig. 1 System Relationships

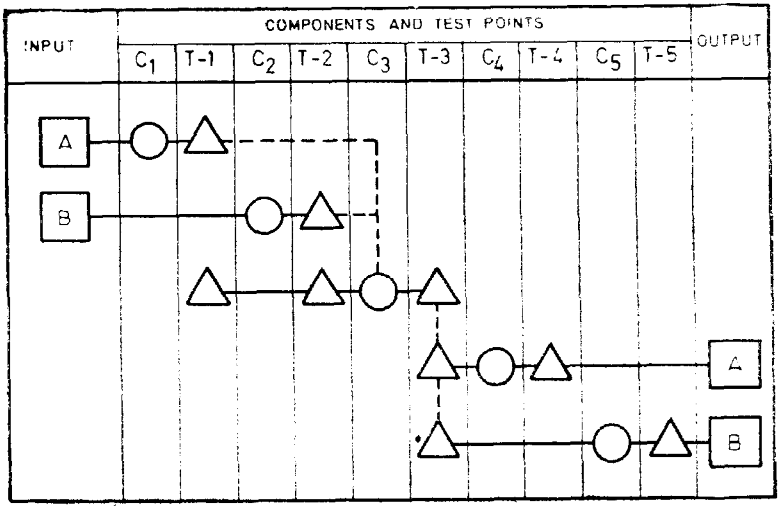

Fig. 2 Functional Dependency, Matrix

A-3.2 The right half of the dependency matrix is developed by assuming that each component foils one at a time and the resultant test pattern would emerge. For example, failure of component C3 would result in test points Tl and T2 testing correctly with the balance testing incorrectly.

A-3.3 Test thoroughness is assessed with the matrix by determining if each replaceable sub-component has associated with it a unique test pattern. The ratio of those testable to the total provides the thoroughness measure. For example, thoroughness equals one since all components are testable.

A-3.4 Accuracy is assessed by determining if there is ambiguity or common test patterns for multiple components. In this example there is no ambiguity. Therefore, accuracy is one. For a more complex system or systems with feedback ambiguity patterns are likely to be present.

A-3.5 The dependency matrix is valuable not only for test effectiveness assessment, but also is useful as a design aid, to assist in test point selection.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2